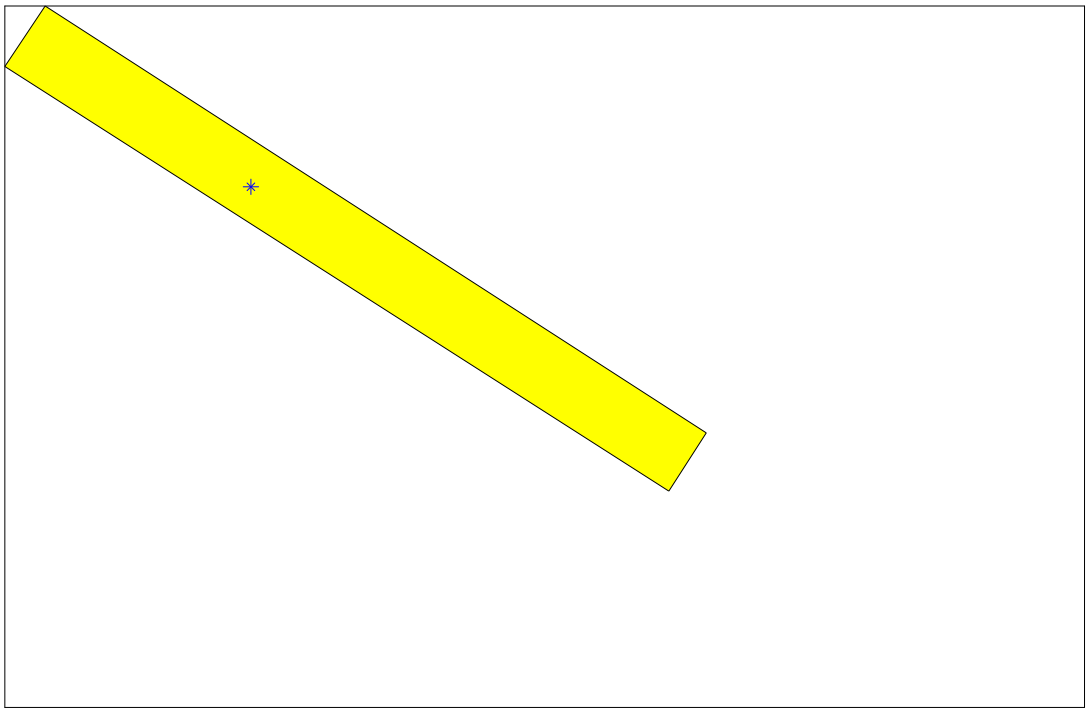
Systematic sampling locations for detecting an area of elevated values (hot spot)

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Formula for calculating number of sampling locations	Singer and Wickman algorithm
Calculated total number of samples	1
Type of samples	Point Samples
Number of samples on map [a]	1
Number of selected sample areas [b]	1
Specified sampling area [c]	7528.90 ft^2
Grid pattern	Triangular
Size of grid / Area of grid [d]	161.326 feet / 22539.3 ft^2
Total cost of sampling [e]	$1,500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid gives the linear and square dimensions of the grid spacing used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: Area 1					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
679069.1729	3083209.8388		0	Hotspot	

Primary Sampling Objective
The primary purpose of sampling at this site is to detect "hot spots" (local areas of elevated concentration) of a given size and shape with a specified probability, 1-β.

Selected Sampling Approach
This sampling approach requires systematic grid sampling with a random start. If a systematic grid is not used, the probability of detecting a hot spot of a given size and shape will be different than desired or calculated.

Number of Total Samples: Calculation Equation and Inputs
The algorithm used to calculate the grid size (and hence, the number of samples) is based on work by Singer and Wickman for locating geologic deposits [see Singer and Wickman (1969) and Hassig et al. (2004) for details]. Inputs to the algorithm include the size, shape, and orientation of a hot spot of interest, an acceptable probability of finding a hot spot, the desired type of sampling grid, and the sampling budget. For this design, the grid size was calculated based on the given hot spot size and other parameters.

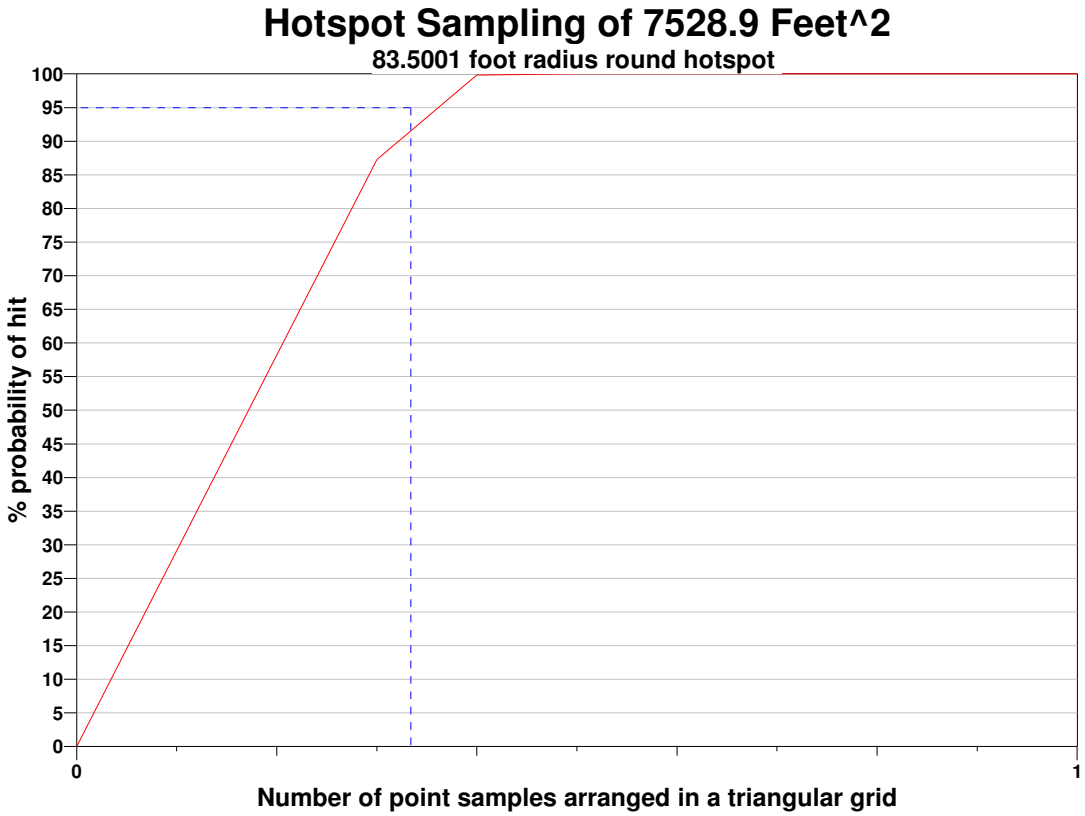
The inputs to the algorithm that result in the grid size are:

Parameter	Description	Value
Inputs		
1-β	Probability of detection	95%
Grid Type	Grid pattern (Square, Triangular or Rectangular)	Triangular
Sample Type	Point samples or square cells	Points
Hot Spot Shape	Hot spot height to width ratio	1
Hot Spot Size	Length of hot spot semi-major axis	83.5001 feet
Hot Spot Area [a]	Area of hot spot (Length^2 * Shape * π)	21904 ft^2
Angle	Angle of orientation between hot spot and grid	Random

Sampling Area	Total area to sample	7528.90 ft^2
Outputs		
Grid Size	Spacing between samples	161.326 feet
Grid Area	Area represented by one grid	22539.3 ft^2
Samples [b]	Optimum number of samples	0.334035
Cost	Total cost of sampling	$1,500.00

[a] Length of semi-major axis is used by Singer-Wickman algorithm. Hot spot area is provided for informational purposes.
[b] The optimum number of samples is calculated by dividing the sampling area by the grid area.

The following graph shows the relationship between the number of samples and the probability of finding the hot spot. The dashed blue line shows the actual number of samples for this design (which may differ from the optimum number of samples because of edge effects).



Assumptions that Underlie the VSP Locating a Hot Spot Design Method

1. The shape of the hot spot of concern is circular or elliptical.
2. The level of contamination that defines a hot spot is well defined.
3. The location of the hot spot is unknown, and if a hot spot is present, all locations within the sampling area are equally likely to contain the hot spot.
4. Samples are taken on a square, rectangular or triangular grid pattern.
5. Each sample is collected, handled, measured or inspected using approved methods that yield unbiased and sufficiently precise measurements.
6. A very small proportion of the surface being studied will be sampled (the sample is much smaller than the hot spot of interest).
7. Sample locations are independent of the measurement process.
8. The systematic grid is placed at a randomly determined starting place to cover the surface area of interest.
9. There are no classification errors (if a hot spot is sampled, it is not mistakenly overlooked or an area is not mistakenly identified as a hot spot).

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the probability of hit (%), hot spot shape (height to width ratio) and hot spot size (length of semi-major axis). The following table shows the results of this analysis.

Number of Samples				
		Size=41.75	**Size=83.5001**	**Size=125.25**
1-β=90	**Shp=0.8**	2	1	1
	Shp=0.9	2	1	1
	Shp=1	2	1	1
1-β=95	**Shp=0.8**	2	1	1
	Shp=0.9	2	1	1
	Shp=1	2	1	1
1-β=100	**Shp=0.8**	3	1	1
	Shp=0.9	2	1	1
	Shp=1	2	1	1

1-β = Probability of Hit (%)
Shp = Hot Spot Shape (Height to Width Ratio)
Size = Hot Spot Size (Length of Semi-major Axis)

Cost of Sampling
The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $1,500.00, which averages out to a per sample cost of $1,500.00. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**1 Samples**
Field collection costs		$100.00	$100.00
Analytical costs	$400.00	$400.00	$400.00
Sum of Field & Analytical costs		**$500.00**	**$500.00**
Fixed planning and validation costs			$1,000.00
Total cost			**$1,500.00**

Recommended Data Analysis Activities
Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2006). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

A map of the actual sample locations will be generated so that the sampling plan and the field implementation may be compared. Deviations from planned sample locations due to topographic, vegetative, or other features will be noted. Their impacts will be qualitatively assessed. If a hot spot is discovered, additional sampling may be performed to determine its size and shape, in which case, the initial assumptions of the sampling design may then be assessed and/or reconsidered.

References
EPA 2006. *Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S*, EPA/240/B-06/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington DC.

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Hassig, N.L., J.E. Wilson, R.O. Gilbert and B.A. Pulsipher. 2004. *Visual Sample Plan Version 3.0 User's Guide*. PNNL-14970. Pacific Northwest National Laboratory, Richland, WA, December 2004.

Singer, D.A. and J.E. Wickman. 1969. *Probability Tables for Locating Elliptical Targets with Square, Rectangular, and Hexagonal Point Nets*. Pennsylvania State University, University Park, Pennsylvania. Special Publication 1-69.